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NOTES AND INSIGHTS

Ethical considerations of using system dynamics in participatory settings: a social-ecological-systems perspective

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Abstract

The social-ecological systems (SES) approach elicits a broad understanding of some of the most pressing socionatural challenges (e.g. resource scarcity, biodiversity loss, and climate change) and the responsibility that humans have in addressing them. System dynamics has proven a powerful paradigm for dealing with complex SES-related issues. Here we discuss some ethical considerations of using system dynamics (SD) to model SES, something that is often either overlooked or discussed as an isolated issue. Sustainable development and human rights are used as ethical standpoints across the modelling cycle, opening the discussion around guiding principles that need to be considered when modelling SES. Based on these, a set of guiding ethical questions are identified and classified across a participatory SD modelling cycle. This structured approach is a simple yet potentially useful tool for SD practitioners to examine the ethical implications of their modelling endeavours in the context of grand societal challenges.

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Introduction

Questions of sustainability have been central to system dynamics (SD) practice throughout the history of the field. *World Dynamics* (Forrester, 1971) and *Limits to Growth* (Meadows *et al.*, 1972) were key in illustrating the impossibility of pursuing infinite economic growth and consumption on a finite planet (Meadows and Meadows, 2007; Randers, 2000), both of which used SD as the modelling paradigm. More than 50 years later, the sustainable development paradigm is now at the centre of the global political agenda (UN General Assembly, 2015), aiming to balance social, economic, and environmental dimensions by taking an intergenerational perspective (Sachs, 2012; United Nations, 1987). System dynamics continues to be relevant in addressing today's global sustainability challenges (Hjorth and Bagheri, 2006; Moallemi *et al.*, 2021; Randers, 2000). For instance, a recent review identifies SD applications across all 17 U.N. sustainable development goals (Moallemi *et al.*, 2021).

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This reflects SD's strength to deal with a broad spectrum of "big issues" or "grand societal challenges" (Kwakkel and Pruyt, 2013; Lane, 2010), as varied as climate change, fisheries, biodiversity conservation, forest fires, water planning, air quality, and waste management, among many others (Collins *et al.*, 2013; Dudley, 2008; Fiddaman, 2002; Ford, 2010; Stave, 2010).

Efforts towards sustainable development should recognise the deeply intertwined nature of human and natural systems (Folke *et al.*, 2016). This idea has been articulated in the concept of social-ecological systems (SES), understood as "interdependent and linked systems of people and nature" (Fischer *et al.*, 2015, p. 145). SES are complex systems nested across multiple interacting scales (e.g. landscape, regional, and global scales) embedded in the biosphere (Fischer *et al.*, 2015; Folke *et al.*, 2021; Preiser *et al.*, 2018). A sustainable development approach aligned with an SES perspective considers that "economic activities are part of the social domain, and both economic and social actions are constrained by the environment" (Wu, 2013, p. 1003). A SES approach is helpful to understand some of the most pressing current sustainability challenges, including climate change, environmental deterioration, and biodiversity loss, (Díaz *et al.*, 2019; Folke *et al.*, 2021; Nelson *et al.*, 2006; Rockström *et al.*, 2009). Designing and implementing policies that deal with such systems is a nontrivial and complex task (de Gooyert *et al.*, 2016; Kelly *et al.*, 2013).

The long-term and holistic focus of SD is helpful in addressing SES-related issues (Elsawah *et al.*, 2017; Kelly *et al.*, 2013). SES interventions often rely on simplistic and short-term perspectives leading to policy choices that are ineffective in reaching their intended objectives, e.g. due to policy resistance, or may even have serious unintended consequences (Collins *et al.*, 2013; Pahl-Wostl, 2007; Sterman, 2006; Sterner *et al.*, 2006). These issues stem from the human-bounded rationality to understand the feedback structures that drive complex systems' behaviour (Sterman, 2002). System dynamics simulation tools offer an alternative to these practices by aiming to capture the systemic structure of an SES problem to subsequently explore its long-term pathways under diverse policy actions (Ford, 2010; Dixson-Declève *et al.*, 2022; Sterman, 2000).

Despite the aforementioned capabilities, here we argue that using SD in the context of complex global socioenvironmental challenges has implications in terms of participation and ethics. In this article, we use an SES lens to explore these implications. The social element of SES calls for participation, and a participatory process opens up ethical concerns and dilemmas. Despite our analysis focusing on the interface between human and environmental systems, our insights remain relevant for SD applications in the context of wider issues (e.g. health, education, migration, climate change, etc.). Therefore, this article's approach of integrating participatory and ethical dimensions does not limit it to SES but can be extended to a wider set of grand societal challenges (e.g. achieving the SDGs).

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The social dimension of SES highlights the importance of developing SD models in a participatory manner. Engaging stakeholders is imperative as they are either interested or affected parties in addressing an SES problem (Király and Miskolczi, 2019; Stave, 2002). System dynamics participatory approaches, like group model building, have a long tradition in organisational contexts and may offer important insights in the context of SES (Hovmand, 2014; Luna-Reyes *et al.*, 2006; Rouwette *et al.*, 2002). Yet, SD participatory approaches in socioenvironmental issues remain relatively sparse (Stave, 2002, 2010; Videira *et al.*, 2009; Videira *et al.*, 2012). For instance, a recent review shows that 70 percent of peer-reviewed SD applications in the context of sustainable development do not report any form of participation (Moallemi *et al.*, 2021). System dynamics practitioners should address the issue of stakeholder participation as a general calling to socioenvironmental modelling approaches (Voinov and Bousquet, 2010; Voinov *et al.*, 2016). This sparseness reiterates our ambition of making the principles in this article with its focus on SES applicable to other modelling foci.

Second, modelling people and the environment goes beyond technicalities and has ethical implications. The SD modelling cycle often gathers modellers and stakeholders with the task of translating "real-world" issues into conceptual and quantitative models to use them to support policy choices or discussions (Freebairn *et al.*, 2019). This process is a complex social construction that is far from objective (Vennix, 2000). It involves activities of judgement, prioritisation, pondering, negotiation, and simplification. Hence, SD models incorporate the values and worldviews of the persons that take an active role in their development (Palmer, 2017). This raises ethical implications that should be explicitly considered and discussed (Nabavi *et al.*, 2017; Pruyt and Kwakkel, 2007). Ethically transparent SD modelling approaches are therefore necessary in the context of SES and beyond.

This article, though using SES as a lens, aims to be useful as an entry point for SD modellers to consider participation and ethics in the context of grand societal challenges. More specifically, we focus on the often-disregarded ethical dimension of SD modelling, illustrated through a socioenvironmental lens. We argue that a structured ethical reflection can take place in the context of any general SD participatory modelling process. We propose two ethical standpoints for SD applications in SES, namely sustainable development and human rights. These standpoints rely on important principles that are helpful to guide SD practice and can be operationalised in the form of ethical questions. In short, the practice of translating relevant guiding principles as a collection of ethical questions should be considered across any SD participatory process to explore the ethical implications of modelling the complex socioenvironmental challenges of our time.

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An ethical lens to modelling SES

Ethics and system dynamics

Ethics is a branch of philosophy that reflects on morals (Kirchschlaeger, 2021), being concerned with what is morally good and bad, right and wrong (Singer, 2022). In simpler words, ethics is "a general concept referring to the way we think about normative issues" (Ormerod and Ulrich, 2013, p. 293). Ethics questions what ought to be (i.e. to what end, on what grounds, and why) "in a rational, logically coherent, methodological-reflective, and systematic way" (Kirchschlaeger, 2021, p. 31). Therefore, an ethical stance can be used to systematically scrutinise the values underlying human actions as well as their consequences (Ormerod and Ulrich, 2013; Rachels and Rachels, 2019). An applied ethics perspective is fundamental to discern the practical implications of current (and future) human endeavours and to question and help to shape them (Kirchschlaeger, 2021). Applied ethics has been used in multiple problems and disciplines (Chadwick, 2012), yet few works have taken such perspective in SD and related fields (e.g. operational research) (Ormerod and Ulrich, 2013; Pruyt and Kwakkel, 2007; Rauschmayer *et al.*, 2009). The present article takes an applied ethics perspective by looking at the practice of SD modelling from an ethical lens.

Ethics is pervasive across the SD practice. This is evident explicitly and implicitly in various ways: in SD theory and practice (e.g. due to SD pragmatic focus on what an issue "ought" to be (Nabavi *et al.*, 2017)); in SD models (e.g. as constructs embedding values of their crafters (Palmer, 2017)); in the professional conduct of SD practitioners (e.g. System Dynamics Society Code of Conduct (System Dynamics Society, 2019)); and in SD institutions (e.g. System Dynamics Society's mission and vision (System Dynamics Society, 2023)). However, the discussion around the ethical considerations of SD remains limited and implicit. Few authors have raised concerns about this, and a more open discussion about the ethical dimension within SD is needed (Palmer, 2017; Pruyt and Kwakkel, 2007).

Perhaps one of the most important realisations to start deliberating about the ethical implications of SD models is to understand them as "engineered" artefacts (Olaya, 2014). As such, models are built with a purpose (Olaya, 2016) and are not neutral (Katz, 2011). They rather are ethically charged entities (Palmer, 2017), embedding the values and worldviews of their crafters. In this line, Palmer (2017) asserts that the moral value of an SD model is evident through the consequences of its practical use (e.g. policy design and implementation). Nevertheless, it is important to realise that the ethical implications of an SD model would depend on the extension of the system boundary that it represents. A system boundary can define a fairly simple system that does not raise important ethical concerns, but as a boundary extends to consider socioenvironmental elements, ethical

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considerations become more critical (Nabavi *et al.*, 2017). The above raises important implications for any participatory approach, with both modellers and stakeholders taking an active and deliberative role during the model-building process.

Ethical motivations for sustainable development and SES

There are various implicit or explicit motivations for taking a sustainable development perspective to manage SES. A first example can be understood as an ethic of survival. Early SD practitioners illustrate such concepts by suggesting that unsustainable resources exploitation might cause future population overshoot and collapse (Forrester, 1971; Meadows *et al.*, 1972). More recently, leading earth scientists have raised similar arguments suggesting that large human-driven environmental changes are surpassing life-supporting "planetary boundaries," posing an existential threat to human civilization (Folke *et al.*, 2021; Rockström *et al.*, 2009). Extreme scenarios such as these challenge both human and other life forms and raise ethical concerns regarding the responsibility and care that humans should have towards the preservation of life from an intergenerational perspective (Berti, 2014).

Beyond survival, various authors have highlighted that justice and human dignity need to be considered in the context of sustainable development. Leach *et al.* (2018) argue that a SES perspective demonstrates the intertwined nature of equity and sustainability. Along a similar line, Gupta *et al.* (2023) propose that planetary boundaries should consider justice and aim to reduce harm, increase basic resources access, and challenge inequalities from an intergenerational perspective. To do so, human rights should protect human dignity by setting a minimum level of access to critical resources for people now and in the future (Gupta *et al.*, 2023; Kirchschlaeger, 2020). Nevertheless, ethical implications arising from considering the value of non-human nature need more attention and could also be considered in a larger framework of "biosphere" responsibility (Folke *et al.*, 2016; Jax *et al.*, 2013).

From the above follows that SES issues are not just "environmental," and that their "social" element has many ethical implications. Recent reports recognise this issue by pointing out that the deep drivers for environmental change lie in people's values and behaviours (Díaz *et al.*, 2019). Donella Meadows already argued in a similar way by pointing out that deep levers to intervene in a system lie in the dimensions of design (i.e. social structures and institutions) and intent (i.e. values, goals, and worldviews) (Abson *et al.*, 2017; Meadows, 1999). Therefore, as Chan *et al.*) summarised: "transformative change towards sustainable pathways requires more than a simple scaling-up of sustainability initiatives—it entails addressing these levers and leverage points to change the fabric of legal, political, economic and other social systems" (2020, p. 694).

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Reflexive SD practice should engage more explicitly with such ethical motivations and deep drivers of change (i.e. values and behaviours) in the context of contemporary grand social challenges. Simulation models can become spaces where abstract ethical concepts (i.e. justice) are considered in a more tangible way. For example, considering the issue of intergenerational justice with respect to access to resources, an SD model can be an entry point to discuss questions such as *how to avoid potential long-term policy maladaptation?* or *how to define "minimum levels of resources" for different groups and across generations?* In that way, models can be used as deliberation spaces of desirable futures.

Two ethical standpoints in SD modelling of SES

In dealing with social-environmental challenges, a sustainable development paradigm is not value neutral (Holden *et al.*, 2017). First, it relies on principles such as intra/intergenerational justice and the precautionary principle (Paterson, 2007; Spijkers, 2018). Hence, designing sustainability policies requires an open deliberation about these principles in order to operationalise them (Karlsson, 2007; McDermott *et al.*, 2013). Second, as humans are at the centre of sustainable development, human rights need to be considered in the context of sustainability (Kirchschlaeger, 2021). This is evident since the UN General Assembly (2022) recently recognised the human right to "a clean, healthy and sustainable environment," implying that every human being is not only a right holder but also a duty bearer towards a sustainable environment. Thus, an ethical lens is necessary to guide sustainability practice (Holden *et al.*, 2017; Leach *et al.*, 2018; de Vries, 2019). Here we propose sustainable development and human rights as general ethical standpoints for coping with SES, and particularly for using SD to model SES.

Sustainable development

Sustainable development has its ethical roots in various principles, most evident of which is arguably the principle of intra- and intergenerational justice which strive for equality or equal treatment of humans within and across generations (Kirchschlaeger, 2021). Intergenerational justice demands that each generation should consider succeeding generations "to satisfy their needs, to avoid serious harm and to have the opportunity to enjoy things of value" (Thompson, 2010, p. 6). Reaching intergenerational justice implies addressing the issue of justice in the present generation (i.e. intragenerational justice) (Sen, 2011; de Vries, 2019) while focusing on today's children as a generational bridge with future generations (Berti, 2014; Thompson, 2010). This continuum is necessary to achieve transformational pathways of "equitable sustainability"

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(Leach *et al.*, 2018). It is noteworthy that various authors have used the concept of equity, both intra- and intergenerational, as strongly related to justice in the context of sustainability (Leach *et al.*, 2018). Notable applications can be found in the fields of conservation (Klein *et al.*, 2015; Schreckenberg *et al.*, 2016; Zafra-Calvo *et al.*, 2017), payment for ecosystem services (McDermott *et al.*, 2013), and resources management (van der Zaag, 2007).

Connected to intergenerational justice is the precautionary principle (Raffensperger and Tickner, 1999), as implying that "we should avoid activities that we have reason to believe could do serious harm to either present or future people" (Thompson, 2010, p. 8). In the context of SES, the precautionary principle enables the adoption of preventive action to protect both humans and the environment when stakes are high in the face of uncertainty (Bourguignon, 2016; Kriebel *et al.*, 2001). Such a broad definition makes the principle's operationalisation a matter of intense academic and even legal debate, usually held at the national and international spheres (Garnett and Parsons, 2017; Paterson, 2007). However, a more widespread implementation of the principle should start moving towards more local and specific contexts (European Environmental Agency, 2013). Likewise, the EEA (2013) warns that addressing current and future controversies around the precautionary principle should learn from past mistakes, as there is an already extensive list of cases where preventive action failed to protect human and environmental health.

The long-term focus of SD can be used to reflect on the implications of considering sustainability principles in the context of current grand societal challenges. Here the "umbrella" concept of sustainability considers many sectors and issues related with economic, social, and environmental systems (e.g. SDGs). System dynamics models can be used to assess how the policies of today may have irreversible impacts for future generations (e.g. loss of health, poverty traps, persistent pollution, species extinction). Specific simulation models (e.g. assessing the potential long-term health impacts of pollution) can add up to improve the contextual understanding of complex trade-offs of benefits and risks not only within but also across generations.

Human rights

Human rights set a minimum standard to protect human dignity (Kirchschlaeger, 2016, 2020), relying on the principles of freedom, equality, and justice (Kirchschlaeger, 2013). It therefore has elements overlapping with those of sustainable development (i.e. justice). Article 1 of the Universal Declaration of Human Rights states that "All human beings are born free and equal in dignity and rights. They are endowed with reason and conscience and should act towards one another in a spirit of brotherhood." Among its characteristics, universality is perhaps human right's strongest attribute, as it "entails that humans are human rights holders and that their human rights

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need to be respected, protected and realized" (Kirchschlaeger, 2021, pp. 160–161). Human rights are therefore an ethical common ground for every human being and human endeavour (Kirchschlaeger, 2016).

Scientific progress encompasses human rights. As an essential part of human existence, human rights protect scientific enquiry, ensuring academic freedom and serving as a fundamental point of reference for scientific practice (Kirchschlaeger, 2013). System dynamics literature is part of the wider context of scientific progress (Forrester, 1987) and therefore is subject to human rights considerations. System dynamicists are expected to protect human rights by: (1) respecting human rights; (2) contributing to the realisation of human rights; and (3) setting priorities according to human rights. These duties can take a negative or positive outlook: by doing or by omitting something in order to contribute to the realisation of human rights.

System dynamics practice should consider explicitly the ethical standpoint of human rights, but this makes more sense on a case-by-case basis. System dynamics practitioners should ask themselves how their SD project can be linked to a specific human right in a positive (e.g. models that help understand how to improve the quality of education) or negative outlook (e.g. models that help understand how to prevent biodiversity loss). Considering human rights in SD also implies an invitation to move away from the role of "neutral modeller" towards an "activist modeller." The latter role has an explicit ethical stance (e.g. based on human rights or sustainable development) regarding a particular issue and uses modelling as an analytical tool to convey a message to change the situation around the problem at hand (Voinov *et al.*, 2014).

Participatory SD modelling and ethics in SES

The need of SD participatory approaches to model SES

The social element of SES calls for promoting participatory modelling approaches. Participation is not a new concept in SD; on the contrary, it can be traced back to the discipline's early stages (Lane, 2010). However, traditional SD group model building often involves a "client" group, resembling a consultancy setting (Andersen and Richardson, 1997). In such a context, Vennix) argues that participation can bring several benefits which include: (i) "to capture the required knowledge in the mental models of the client group"'; (ii) "to increase the chances of implementation of the model results", and (iii) "to enhance the client's learning process" (2000, p. 379). However, a broader set of perspectives in favour of participation can be considered when dealing with socioenvironmental issues (Norström *et al.*, 2020; Voinov *et al.*, 2014). For instance, recent research shows how participatory modelling can enrich the understanding of complex social interconnections

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in the context of local sustainability transitions (Szetey *et al.*, 2023). Or how integrating local knowledge in formal SES assessments recognise the stakeholders' role in a socioenvironmental issue and foster reflection about the impact of their actions, priorities, and visions (Norström *et al.*, 2020; Rodríguez *et al.*, 2023).

Current SD participatory practice promotes wider stakeholder participation in the context of social change and environmental management. This has been done by promoting democratic participation and social capital strengthening to favour transparency and deliberation in a multistakeholder debate around socioenvironmental issues (Király and Miskolczi, 2019; Stave, 2002). However, adopting such an approach brings up ethical considerations arising from the interaction between modellers and stakeholders, for example, in terms of power, justice, and knowledge (Jordan *et al.*, 2018; Norström *et al.*, 2020). Recent community-based SD initiatives have taken a proactive approach to empower marginalised communities in dealing with complex social problems (Gallagher *et al.*, 2020; Hovmand, 2014; Király and Miskolczi, 2019; Trani *et al.*, 2016). Participatory SD modelling has been used in the context of transdisciplinary environmental management and policy (Stave, 2010). This article builds on the latter approach as it explicitly deals with the interaction between society and environment in the context of a public policy debate.

In this context, Videira *et al.* (2010) proposed a participatory modelling cycle aiming to be implemented in the context of environmental assessment and decision-making. This framework involves the following phases: (1) scoping and abstraction; (2) envisioning and goal setting; (3) model formulation and confidence-building; (4) simulation and assessment, and (5) evaluating and monitoring. This SD based framework promotes continuous stakeholder participation to learn about SES and deliberate about policy alternatives to sustainability problems. Here we build on the Videira *et al.* (2010) framework and use it to explore the ethical implications of modelling SES, taking human rights and sustainable development as standpoints.

Ethical considerations can be identified across a participatory modelling cycle. Starting from the scoping and abstraction phase, stakeholders need to be able to meaningfully engage in the process and be able to question and define the limits of the issues at hand. They should have a voice in envisioning desired future(s) for the system. Their role can be key in validating the model's structure and outputs. Towards the end of the modelling cycle, stakeholders should be able to use simulation outputs as a starting point for discussing policy options. The following section examines these considerations in more detail, while explicitly considering human rights and sustainable development.

Asking ethical questions in SD SES participatory processes

Asking ethical questions is a practical approach to integrate ethics into SD modelling practice. Ethical questions inquire about values and responsibility,

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particularly regarding conflicting notions of the good (Ormerod and Ulrich, 2013). Nabavi *et al.* (2017) point out that defining boundary conditions in SD requires ethical judgement as it not only deals with the question of what "*is*" but also of what "*ought*" to be. They also reflect that the latter should be explicitly done within an ethical framework (e.g. sustainability principles). Pruyt and Kwakkel (2007) and Palmer (2017) offer a set of ethical questions to guide the implementation of a system dynamics assessment. However, it is important that these questions are asked following a logical order. To aid the aforementioned issues, this article proposes the classification of these questions across the SD participatory modelling cycle in the context of SES using two ethical standpoints.

Asking ethical questions is relevant for the SD stakeholder participation cycle across a broad range of modelling studies as they deal with matters that affect people and the environment. Here the ethical standpoints of human rights and sustainable development need to be explicitly considered in the context of SES. Table 1 shows some relevant ethical questions to be examined across SD applications in the context of SES while considering the two central standpoints in this article. The proposed set of questions is general and therefore not exhaustive. Rather it is meant to be a starting point to promote a discussion about the ethical implications that emerge across the SD modelling cycle and for a range of SD modelling studies in areas beyond SES. More tailored questions will likely rise while discussing ethical concerns in specific SD applications around SES. The following sections offer a detailed discussion of the questions applicable within each phase of the participatory modelling cycle as proposed by Videira *et al.* (2010).[i]

Scoping and abstraction

Practical questions such as delimiting the problem or system in space and time requires ethical judgement (Nabavi *et al.*, 2017), especially when dealing with complex SES, but should also be applicable to other systems. Likewise, determining who will participate and their motivations is necessary to have a wider understanding of the world views that will be embedded in the model. Yet, having a reflection of perspectives that are *excluded* from the modelling process is useful to be aware of the model's limitations. This reflection may highlight the need to include new participants. New stakeholders can be considered, for instance, based on human rights (e.g. people whose rights might be potentially affected by policy outcomes of the modelling process (Gallagher *et al.*, 2020)) or sustainable development (key stakeholders who are potentially responsible for (un)sustainable outcomes in SES (Videira *et al.*, 2012)). The analysts' self-reflection about their role and motivation is key in this process. Although neutrality is often a desired quality,

[i]As we are only focusing on the ethical aspects of modelling and not the actual policy implementation, the "monitoring and evaluation" phase as proposed in Videira *et al.* (2010) is not discussed here.

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Table 1. Guiding ethical questions across a System Dynamics framework.

Scoping and abstraction	Envisioning and goal setting	Model formulation and confidence building	Simulation and assessment
• Who matters? * • What matters? * • What time horizon matters? * • What are the boundaries of the system/model to be considered? * • What is the time frame considered? * • Who participates? * • **Whose world-view, value system, perspective, and interests are taken into consideration?** • Who decides from what perspective? * • What is the role of the analyst? *	• What dimensions are considered important? * • Do the participants/stakeholders determine the dimensions to be considered? * • **What is "sustainability" in the specific context for different stakeholders?** • What do the stakeholders want to "sustain" and for how long?† • **Is there agreement regarding vision of a desired "sustainable future" among stakeholders? If not, whose perspective is more visible? Why?** • **Who might be positively or negatively impacted if this vision is reached?** • **Are the visions of a "sustainable future" intra/intergenerationally just? How are future stakeholders (i.e. children, coming generations) considered in it?** • **Do the visions of a "sustainable future" prevent potential harm?** • **Does the envisioning and goal setting potentially infringe human rights?** • **Does the envisioning and goal setting phase take active responsibility in human rights protection? How? – by respecting human rights? by contributing to the realisation of human rights? by setting priorities according human rights?**	• Have the modeller/analyst made all possible input to the model as objective as possible?** • How have the modeller/analyst introduced bias into the model? ** • **How is the modeller/analyst communicating such bias to the stakeholder group and the general public?** • **How is the modeller/analyst reflecting about his/her own motivations, worldviews and goals are incorporated in the model?** • How accurate is the representation of society in the model? ** • **Does the model reflect the structure found in the real-world?** • What other design options are possible? ** • **Does the model reflect the behaviour of the real-life problem/system based on a selected set of indicator values?** • **Do stakeholders agree to use the simulation model based on its capabilities to balance the complexity reflected in the conceptual maps and the simplicity required for quantification?**	• Will the model be used to develop policy? ** • What is the level of uncertainty (robustness)? ** • What will the policy do to society if the causal assumptions in the structure are wrong? ** • Have the modeller/analyst communicated the uncertainty to decision-makers? ** • Will the policy developed from the model create harm for society if the assumptions are indeed incorrect? ** • Does the policy produce the good for which It was intended? ** • Are there foreseeable unintended side effects? ** • Do the side effects of implemented policy indicate that the model design is inaccurate? ** • **How to weigh the criteria and assess the performance of policy options? (who selects the criteria? Why? To what end?)** • **How can stakeholders incorporate the insights of the "envisioning and goal setting" to inform their decision-making process?**

Note: Questions in bold are newly proposed in this article, with the remainder from various sources: *Pruyt and Kwakkel (2007), **Palmer (2017), and †Stave (2010).

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modelling is not objective. That is why analysts should identify and be reflexive about their own motivations, world views, and goals and question how they bring them into the modelling exercise (Ives *et al.*, 2020; West and Schill, 2022).

Envisioning and goal setting

This phase's ethical challenges relate to the definition of criteria and the system's vision(s) of the future, something critically important when dealing with SES and many broader global grand challenges, including climate change, biodiversity loss, and ecosystem changes. It is important to define the criteria that will be useful to assess the performance of future interventions. To this end, the umbrella concept of "sustainability" can be used to discuss and agree on a specific definition for each particular context (Videira *et al.*, 2010). An active approach towards human rights protection should be the fundamental ethical ground for the discussion of desired futures. Similarly, to envision multiple desired futures (scenarios) will help stakeholders define more explicitly which futures they value the most and why. An in-depth enquiry regarding these aspects should consider principles related with sustainable development, such as intra/intergenerational justice and the precautionary principle. Likewise, it is important to have a vision of how the participatory process of discussing and agreeing would make certain criteria and visions of the future more visible while, almost inevitably, others become less visible.

Model formulation and confidence building

The role of the analyst is central as the main actor developing SD quantitative models. A conscious effort to craft a model that balances simplicity and complexity is key. Not every aspect from conceptual mapping can be quantified in a simulation model, yet the model needs to reflect the complexity and behaviour of the real system or issue at hand. The modellers should recognise themselves as a very likely source of bias and consider how they are actively looking to identify and minimise it, as well as trying to make explicit the remaining bias. This process can be made more transparent by involving stakeholders in the validation phase.

Simulation and assessment

If a model is used to support policy, its strengths and limitations must be openly discussed and recognised by stakeholders. An important limiting aspect of simulation models is uncertainty. Recognising and communicating uncertainty is therefore critical (Palmer, 2017). Assessing the model's robustness can help to discuss the risks of using models to support policy decisions by considering multiple scenarios (Moallemi *et al.*, 2020). Finally, it

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might be valuable at this stage to reexamine the implications of choosing certain policy alternatives to reach a desired "sustainable future" accounting for human rights aspects, according to the "envisioning and goal setting" phase.

Promoting ethical exploration in SD modelling

A broader and deeper ethical discussion is necessary in SD and other modelling disciplines. The practice of asking ethical questions is relevant for any SD participatory process to explore the ethical implications of modelling society and the environment. Ethical questioning can be aligned with other processes and practices taking part in a modelling cycle. For instance, this approach may be a foundation for implementing future "ethical" scripts for SD group model-building interventions (Andersen and Richardson, 1997; Hovmand *et al.*, 2012; Luna-Reyes *et al.*, 2006). Such scripts ideally would not only deal with a particular issue at hand but would also facilitate the operationalisation of reflection and discussion around the principles underlying human rights and sustainable development in participatory settings. This is a hopeful direction, as facilitated group ethical discussion can help to enrich the skill of judgement, or "practical wisdom," to cope with contesting values, reach agreements, and move towards action in complex settings (West and Schill, 2022).

In addition to the group ethical exploration, SD modellers would be able to better understand the ethical dimension of their practice by improving personal skills such as reflexivity, accountability, and deliberation. These skills can be strengthened, for example, by having reading groups to broaden the knowledge about ethics and philosophy, or by recording personal video diaries as places to share questions, challenges, and feelings related to the development of an SD project (West and Schill, 2022). Better individual ethical-related skills will very likely, in turn, enrich ethical reflection in a group environment. Exploring these and other novel ways to promote skills that facilitate ethical deliberation is a promising field for research that may benefit SD education and practice.

Concluding remarks

System dynamics practice has ethical implications, evident through: (i) exploring the whole SD participatory cycle with an ethics lens and (ii) considering SD applications, e.g. sustainable development, resource management (Pruyt and Kwakkel, 2007). An ethical perspective also allows one to recognise SD models as entities that encapsulate various stakeholders' values and world views, especially when considering models of potential futures and how those futures might look. Using social-ecological systems as a lens for analysis, this article provides a structured framework aiming to

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make explicit both the critical role of stakeholder participation in SD modelling, and the ethical implications within that modelling cycle, especially in the context of sustainable development.

Sustainable development and human rights were presented as ethical standpoints for SD across the modelling cycle. Sustainable development applications require an open discussion around the concepts of intra/intergenerational justice and the precautionary principle. Human rights protect system dynamicists' freedom to develop research, but demand their responsibility towards human rights recognition and protection in relevant modelling studies.

System dynamics practitioners and researchers should adhere to certain principles across the modelling cycle regardless of the field of study. For instance, the System Dynamics Society's code of conduct encourages its members to adhere to three main principles: (i) contribute to society and human well-being, (ii) prevent conflict of interests, and (iii) respect diversity and prevent discrimination (System Dynamics Society, 2019). Here we propose considering some principles of special relevance for the SD community in addition to the aforementioned:

- The underlying principles of human rights (i.e. freedom, equality, and justice) need to be a fundamental guide for the SD practice;
- System dynamics modellers involved in sustainable development applications need to adhere to the principles of *intra/intergenerational justice* and *precaution*, particularly when dealing with socioenvironmental issues;
- System dynamics studies and applications must be transparent and explicit, especially regarding its assumptions and limitations in face of uncertainty. Palmer (2017) further emphasises the need for *transparency* across the SD modelling process.

This list, though far from exhaustive, highlights the importance to keep identifying and discussing ethical principles that are necessary to guide the SD practice. We acknowledge that our proposed principles interact with the SDS list and help to complement and enrich it. For example, a human rights perspective makes the principle of "contributing to society" more tangible and clearly fosters the respect of diversity and the prevention of discrimination. Transparency is also aligned with the prevention of conflict of interests. It is hoped that this article will contribute to making modelling processes, especially those with a strong stakeholder engagement and participatory component, more ethically transparent, and ultimately more relevant to an increasingly complex world in which policy is ever-more guided by simulation models and their outcomes.

This article should be read as a starting point, and an invitation, to further discuss and address the ethical implications of SD applications in a

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participatory modelling context in general. It proposes a set of principles and ethical questions that need to be discussed along with stakeholders in the context of modelling projects dealing with complex issues. This structured "questioning" approach is a simple yet potentially useful tool for SD practitioners to examine the ethical implications of their modelling endeavours in the context of grand societal challenges, including climate change, migration-related challenges, and the implications of ecosystems degradation. More ethical-aware approaches of operational modelling can build upon the above in the form of "ethical scripts" for future group model-building initiatives (Andersen and Richardson, 1997; Hovmand *et al.*, 2012; Luna-Reyes *et al.*, 2006). These questions may inspire SD practitioners to take part in other practices that improve the reflexivity (e.g. reading group discussions about philosophy and ethics) and deliberation (e.g. personal video diaries) around their modelling endeavours (West and Schill, 2022).

Going forward, continued ethical deliberation is necessary both to prevent violations to important rights and principles but also for taking a proactive approach to achieve the "good" in a "sustainable" future. As a first step, this process can start with the modellers' self-assessment as active ethical actors. System dynamics practitioners make many choices throughout the modelling process, i.e. how you steer stakeholders to frame the problem; or what you emphasise in a conceptual diagram; what you include in, and exclude from, the simulation model; the variables/results that are chosen to be made visible and reported; and what potential interventions you test with your model, their implications, and the assumptions built into them. Our proposed ethical questions aim to help revealing these practices towards a more reflexive and transparent SD modelling practice.

The recognition of ethics as pervasive across the SD practice should hopefully lead to more widespread discussions among practitioners and experts. Operationalising ethics in SD requires reflecting on how abstract concepts (e.g. justice and precaution) take shape in the context of concrete case studies. Participatory modelling approaches allow the opportunity to discuss the implications of such practical ethical insights. System dynamics is a powerful tool to support sustainable policy making, and as such it should point to objectives that promote human dignity and protect the environment. An ethics lens can serve as a compass to guide this process.

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